(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 410 974 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
04.08.2021 Bulletin 2021/31

(21) Application number: **17703104.4**

(22) Date of filing: **01.02.2017**

(51) Int Cl.:
A61F 9/007 *(2006.01)*

(86) International application number:
PCT/EP2017/052103

(87) International publication number:
WO 2017/134077 (10.08.2017 Gazette 2017/32)

(54) SURGICAL MASTER-SLAVE ROBOT

CHIRURGISCHER MASTER-SLAVE-ROBOTER

ROBOT MAÎTRE-ESCLAVE CHIRURGICAL

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **04.02.2016 EP 16154172**

(43) Date of publication of application:
12.12.2018 Bulletin 2018/50

(73) Proprietor: **Preceyes B.V.**
5600 MB Eindhoven (NL)

(72) Inventors:
- **NAUS, Gerrit Jacobus Lambertus**
  5612 DV Eindhoven (NL)
- **MEENINK, Hildebert Christiaan Matthijs**
  7221 GD Steenderen (NL)
- **BEELEN, Maarten Joannes**
  5262 CP Vught (NL)
- **DE SMET, Marc Joseph Dominique**
  1052 Mont sur Lausanne (CH)

(74) Representative: **DeltaPatents B.V.**
Fellenoord 370
5611 ZL Eindhoven (NL)

(56) References cited:

WO-A1-00/30557	**WO-A1-95/10218**
WO-A1-96/39944	**US-A- 5 697 939**
US-A1- 2004 261 179	**US-A1- 2015 245 875**

- **ALI UNERI ET AL: "New steady-hand Eye Robot with micro-force sensing for vitreoretinal surgery", BIOMEDICAL ROBOTICS AND BIOMECHATRONICS (BIOROB), 2010 3RD IEEE RAS AND EMBS INTERNATIONAL CONFERENCE ON, IEEE, PISCATAWAY, NJ, USA, 26 September 2010 (2010-09-26), pages 814-819, XP031793378, ISBN: 978-1-4244-7708-1**

EP 3 410 974 B1

Description

FIELD OF THE INVENTION

[0001] The invention relates to a surgical master-slave robot for use in minimally invasive surgery which comprises an instrument manipulator and a linkage system for moveably suspending the instrument manipulator. The invention further relates to a surgical master-slave robot comprising a cannula connector for connecting the instrument manipulator to a cannula.

BACKGROUND OF THE INVENTION

[0002] Robotically assisted surgery with a master-slave system may assist a surgeon in performing a minimally invasive surgery. Typically, the slave system performs the actual surgery, by means of instrument manipulators which handle surgical instruments. The surgeon remains in control of the instruments by operating a master. A temporarily removal of an instrument manipulator from a surgical position proximate to a subject may be desired, for example, to make sufficient room for the surgeon to perform surgery by hand. In some surgical operations, e.g., eye surgery, the surgeon may need to accesses the subject for manual surgery multiple times during the operation. Thus the temporarily removal of the instrument manipulator from the proximity of the subject for to perform manual surgery and then return of the instrument manipulator back to the surgical position to continue the minimally invasive surgery may be required multiple times during the operation. Due to such repetitions, besides the requirement of providing sufficient room at the surgical position after the temporary removal of the instrument manipulator, a stable and quick removal of the instrument manipulator is often desired. When the removal is repeated multiple times, stability of the removal may, in general, help to avoid damage to the tissue under surgery and also to the robot. In addition, in emergency cases, a quick removal of the instrument manipulator may be particularly preferred.

[0003] US 20040261179 A1 describes a method and apparatus for the mounting of surgical setup arms to the table pedestal or floor below an operating table. The ceiling-height-mounted robotic arm assembly and below-table-mounted robotic arm assembly may be preconfigured to be ready for surgery while the fixable set-up arms are disposed generally clear of the personnel-usable space adjacent the operating table. The ceiling mounted setup arm is said to comprise at least one parallelogram-link structure. Each parallelogram may be raised and lowered vertically, with minimal residual force, with gas springs being selected to support the majority of the system weight throughout the range of motion.

[0004] Other surgical robotic systems which are suitable for use in minimally invasive surgery on a subject are described by each of WO 00/30557 A1, US 2015/245875 A1, WO 95/10218 A1, ALI UNERI ET AL: "New steady-hand Eye Robot with micro-force sensing for vitreoretinal surgery", and WO 96/39944 A1.

[0005] A publication titled "Vitreo-retinal eye surgery robot; sustainable precision, 2011, H.C.M. Meenink, PhD Thesis" describes a surgical master-slave robot for use in minimally invasive surgery. The surgical master-slave robot of Meenink comprises an instrument manipulator and a parallelogram linkage system for positioning the instrument manipulator. The linkage system is configured to rotationally move the instrument manipulator from a surgical position proximate to a subject to a standby position distal to the subject. During the rotational movement, the instrument manipulator is suspended on a suspension point of the instrument manipulator via a linkage component coupled to the instrument manipulator.

[0006] A problem of the surgical master-slave robot of Meenink is that the instrument manipulator is insufficiently stable during the removal of the instrument manipulator and, moreover, after the removal, the instrument manipulator still remains in the surgeon's workspace of manual surgery through which the surgeon's hands move, or through which instruments are handed to the surgeon.

SUMMARY OF THE INVENTION

[0007] It would be advantageous to have a surgical master-slave robot which addresses at least one of the above problems.

[0008] To better address this concern, a first aspect of the invention provides a surgical master-slave robot for use in minimally invasive surgery on a subject, wherein the surgical master-slave robot is defined by claim 1.

[0009] The above measures involve an instrument manipulator for mounting of a surgical instrument. Instrument manipulators for surgical master-slave robots are known in the art per se. The instrument manipulator may be, for example, a mount. The instrument manipulator may be affixed to the robot and thereby take over the tasks of the surgeons hand by handling and manipulating surgical instruments or surgical tools. A surgical instrument may be a specially designed tool or device for performing specific actions of carrying out desired effects during a surgery or operation, such as modifying biological tissues, or to provide access for viewing it. Examples of such surgical instruments include, but are not limited to, forceps, mechanical cutters, coagulation cutters, scissors, injection needles, sealing devices, etc.

[0010] The above measures further involve a linkage system for moveably suspending the instrument manipulator. Examples of linkage systems range from the four-bar linkage used to amplify force in a bolt cutter or to provide independent suspension in an automobile, to complex linkage systems in robotic arms and walking machines. In a linkage system, linkage components such as bars (also referred to as links) may be connected to one or more other links by, for example, pin joints (also referred to as hinges), sliding joints, or ball-and-socket joints so as to form a closed chain or a series of closed chains. A linkage component may be connected to a body, e.g. an instrument manipulator, to suspend and/or move the body. The connection point of the body and the linkage component may be referred to as a suspension point. In the present robot, the linkage system comprises a first linkage component coupled to the instrument manipulator at a first suspension point of the instrument manipulator. The linkage system further comprises a second linkage component coupled to the instrument manipulator at a second suspension point of the instrument manipulator. Linkage systems, also referred to as linkages, are known in the art per se.

[0011] It is an insight of the inventors that with the invention as claimed, upon a temporary removal, sufficient room for a surgeon will be provided while at the same time the instrument will remain compact and close to the surgeon to be returned when desired, without restricting the surgeon's performance. This effect is achieved namely by providing the configuration and arrangement of the instrument manipulator and the linkage system and their coupling as claimed which enable a combined translational and rotational movement of the instrument manipulator during a repositioning. As opposed to the present invention, in the prior art robot of Meenink the instrument manipulator is only rotated upon a temporary removal of the instrument manipulator which will result in an insufficient working space. Rotating the system further away would solve this problem, but will require more room for the system to rotate through and will make the return of the instrument manipulator to the surgical area more difficult. This problem of the prior art robot is solved in an inventive way by the inventors, by arranging the linkage system so that a selected translational movement, which may refer to a rigid displacement without a rotation, is added to a selected rotational movement which enable a flexible in-plane as well as spatial movement of the instrument manipulator in any desired direction along a predefined trajectory. Here, the rotational movement may be established by each suspension point being guided along a differently shaped motion trajectory, whereas same-shaped motion trajectories provide only translation.

[0012] For example, the linkage system may be arranged to enable repositioning of the instrument manipulator by removing the instrument manipulator by a small-radius rotation and then moving the instrument manipulator by a translational-rotational movement to a position outside the surgeon's working space, e.g., below the working space area. As such, sufficient space will be provided for the surgeon to manually perform surgical tasks while at the same time the robot remains compact and sufficiently close to the surgeon for convenient return of the robot back to the surgical area when desired.

[0013] In addition to the above advantage, the inventors have the insight that by the arrangement and the configuration of the instrument manipulator and the linkage system as claimed, the instrument manipulator is suspended on two suspension points during the movement. As a result, the robot and the instrument manipulator will remain stable during the temporal movement. As such, the system may advantageously be less vulnerable when moved away. Moreover, compared to a less robust and stable system such as that with one suspension point, the system with increased stability may help to avoid inducing damage to the tissue under surgery upon the removal. Moreover, by being guided along a predefined trajectory, the movement of the instrument manipulator may be constrained to said trajectory, which facilitates assuming the surgical position from the stand-by position and vice versa. As such, the instrument manipulator may be easily moved from its standby position along the predefined trajectory to the surgical position, e.g., to easily (re)connect to a trocar.It is noted that the robust design of the robot according to the invention may be advantageous not only for the removal of the instrument manipulator but also for accurate return and repositioning of the instrument manipulator back to the surgical position to resume the robotic surgery. Stabilized instrument positioning may also enhance dexterity on surgical tasks and the present invention, as such, discloses a more robust surgical master-slave robot for use in minimally invasive surgery.

[0014] Optionally, said movement of the instrument manipulator causes a tip of a distal end of the instrument manipulator to move along a third movement trajectory, wherein an end portion of the third movement trajectory proximate to the subject is oriented in a direction perpendicular to a surgical entry surface of the subject. This is advantageous in that the removal of the instrument manipulator from an entry site of the surgical instrument on the subject may be safer for the patient when the instrument manipulator is removed in a substantially perpendicular direction. Deviation above a threshold, e.g., 22.5° degrees, from this perpendicular direction may damage a tissue of the subject upon removal of the instrument manipulator. For example, when the instrument manipulator is coupled to a cannula at a proximal end, substantial deviations of the removal of the instrument from substantially perpendicular orientation, e.g., parallel to a central symmetry axis of the cannula, may exert lateral forces to the cannula which may be harmful for the patient. It is further noted that directions within the range of 90 $\pm$ 0 degrees, 90° $\pm$ 2° degrees, 90° $\pm$ 5° degrees, 90° $\pm$ 10° or 90° $\pm$ 22.5° degrees may be considered substantially perpendicular directions for obtaining a safe removal of the instrument manipulator.

[0015] Optionally, the standby position is located laterally sideways with respect to a sagittal plane of the subject and the linkage system is configured for guiding the instrument manipulator laterally sideward with respect to the sagittal plane during the movement from the surgical position to the standby position. Such repositioning of the instrument manipulator may advantageously result in the removal of the instrument manipulator from the area directly above the subject which may be an important area for the surgeon, for example, in an emergency or to perform regular manual tasks during operations.

[0016] Optionally, the standby position is located lower than the subject and the linkage system is configured for guiding the instrument manipulator downward with respect to a coronal plane of the subject during the movement from the surgical position to the standby position. Advantageously, such repositioning of the instrument manipulator may provide further room to the surgeon to have access to the area around the subject and the surgical entry site. For example, repositioning of the instrument manipulator below a subject may provide sufficient space for a surgical assistant to give surgical tools to the surgeon. It is noted that repositioning may, in general, refer to a change in position, e.g., changing from the surgical position to the standby position or vise versa.

[0017] The surgical master-slave robot comprises a release mechanism as defined by claim 1; and the movement of the instrument manipulator is obtained as a result of force acting upon the instrument manipulator as defined by claim 1 when the release mechanism releases the instrument manipulator, wherein the force may be generated by gravity and/or a preloaded spring. Such gravity and/or preloaded spring actuated removal of the instrument manipulator is advantageous in that it makes the removal more convenient as a surgeon or other personnel do not have to waste energy to accurately reposition the instrument manipulator every time the removal is required. This would be particularly advantageous when the instrument manipulator is required to be removed multiple times during an operation. With such gravity and/or a preloaded spring actuation, a separate electrical actuator, which may fail in case of, e.g., power failure, may not be required. As such, the release mechanism may be more robust and reliable.

[0018] Optionally, the release mechanism comprises a hook, a lock arm pin, and a release actuator, wherein the hook is arranged and configured for gripping the lock arm pin; the lock arm pin being connected to one of the first linkage component, the second linkage component or the instrument manipulator via a lock arm, and the release actuator is arranged and configured for releasing the hook from the lock arm pin. By moving the hook toward the lock arm pin, the hook may simply grip the lock arm pin and thereby lock the mechanism, and the lock may be simply released by activating the release actuator, e.g., by way of pushing a handle of the release actuator. As such, the described locking mechanism may enable a quick and convenient release and repositioning of the instrument manipulator when desired. Furthermore, such locking mechanism may enable an accurate return of the instrument manipulator back in place to the surgical working space to continue the operation tasks by the surgical instrument when desired.

[0019] Optionally, the linkage system is provided with a manual actuation handle for enabling a user to manually actuate the linkage system so as to move the respective suspension point of the instrument manipulator along the respective movement trajectory. This may allow convenient control of a user of the movement of the instrument manipulator when desired. By actuating the linkage system via the handle, an easy control of the function of the linkage system may be advantageously obtained.

[0020] Optionally, the surgical master-slave robot comprises an actuator for actuating the linkage system so as to move the respective suspension point of the instrument manipulator along the respective movement trajectory. Including the actuator may enable an automatic actuation of the linkage system and thereby an automatic control of the movement of the instrument manipulator.

[0021] Optionally, at least one of the first linkage component and the second linkage component comprises or is constituted by a slider for sliding along a guide shaped to establish the respective movement trajectory. Advantageously, the guide may simply provide the respective trajectory for the slider and the movement may be thus simply performed by sliding the slider along the guide. Using sliders in the linkage system may be, in general, advantageous in obtaining a smooth and guided movement of the suspension points in the desired movement trajectories. A slider may be, for example, a carriage which may slide on a track.

[0022] Optionally, at least one of the first linkage component and the second linkage component is a rod member rotatable about a rotation point and a rotation of the at least one of the first linkage component and the second linkage component about the rotation point provides said movement of the respective suspension point along the respective movement trajectory. Advantageously, various movement trajectories may be achieved simply by using rod members with different lengths.

[0023] Optionally, one or both of the first movement trajectory and the second movement trajectory are arc-shaped movement trajectories. Although the movement trajectories may have any shape, arc-shaped movement trajectories may advantageously enable a desired rotation of the instrument manipulator such that an optimal route for the movement of the instrument manipulator may be selected.

[0024] Optionally, the surgical master-slave robot further comprises a cannula connector for coupling to a cannula, wherein the cannula provides an opening at the surgical entry surface of the subject for the surgical instrument to enter an interior of the subject, and wherein the cannula connector:

- is coupled to the instrument manipulator at a proximal end;
- comprises a through passage for allowing the surgical instrument to pass through the through passage; and
- is shaped to fit a shape of the cannula so as to establish a releasable coupling with the cannula which releases when the instrument manipulator moves in the direction perpendicular to a surgical entry surface

of the subject.

[0025] Cannulas are known in the art per se. The cannulas may enable easy switching between surgical instruments, making use of the same entry point without unnecessarily puncturing a tissue of the subject at multiple places. Furthermore, the cannulas may provide a 'safety boundary' between the surgical instruments and the tissue, protecting the tissue. By using a cannula connector between the instrument manipulator and the cannula that is aligned with a longitudinal axis of the surgical instrument, sideways forces on the surgical instrument may be prevented as the cannula connection may force the cannula to be aligned with the instrument manipulator and thereby with the surgical instrument.

[0026] Optionally, the cannula has a conical shape and wherein the cannula connector is conically shaped to fit the conical shape of the cannula. The conical shape may allow the instrument manipulator with the cannula connector to be easily positioned onto and aligned with the cannula. The angle of the conical shape may be such that the cannula may not rotate underneath the cannula connector such as a ball joint would. Furthermore, the angle of the conical shape may be such that the cannula may be loosened easily when the instrument manipulator is excluded away from the area for surgery. This may be particularly advantageous when a quick release is required during the operation, e.g., due to emergency. It is also advantageous when the removal of the instrument manipulator is to be repeated multiple times during the surgery, e.g., to allow a manual surgery by the surgeon.

[0027] It is noted that the conical shape may allow the instrument manipulator to be put in place, even when the cannula is not aligned with the cannula connector. The cannula connector may guide and rotate the cannula such that the cannula aligns when the instrument manipulator is introduced.

[0028] Optionally, the cannula and the cannula connector are rigidly coupled. Sufficiently stiff coupling may ensure sufficient stability and reliability of the connections between the cannula and the cannula connector and may minimize sideways deflections resulting from interaction forces.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] These and other aspects of the invention are apparent from and will be elucidated with reference to the embodiments described hereinafter. In the drawings,

Fig. 1a shows a configuration of a linkage system for moveably suspending an instrument manipulator of a surgical master-slave robot;

Fig. 1b shows a translational and rotational movement of the instrument manipulator obtained by rotation of a first rod member and a second rod member in a clockwise of rotation;

Fig. 1c shows an example of an instrument manipulator and the linkage system of the surgical master-slave robot of Figs. 1a-b;

Fig. 2a shows another configuration of a linkage system for moveably suspending an instrument manipulator;

Fig. 2b shows a translational and rotational movement of the instrument manipulator obtained by rotation of a first rod member and a second rod member in opposite directions of rotation;

Fig. 3a shows another configuration of a linkage system for moveably suspending an instrument manipulator;

Fig. 3b shows a translational and rotational movement of the instrument manipulator obtained by rotation of a first rod member and a second rod member in a counterclockwise direction of rotation;

Fig. 4a shows another configuration of a linkage system for moveably suspending an instrument manipulator, wherein the first linkage component is a slider and the second linkage component is a rod member;

Fig. 4b shows a translational and rotational movement of the instrument manipulator obtained by a rotation of the rod member and sliding of the slider along a substantially straight path;

Fig. 5a shows another configuration of a linkage system for moveably suspending an instrument manipulator, wherein the first linkage component is a slider and the second linkage component is a rod member;

Fig. 5b shows a translational and rotational movement of the instrument manipulator obtained by a rotation of the rod member and sliding of the slider along a curved path;

Fig. 6a shows a release mechanism for holding and releasing the instrument manipulator;

Fig. 6b shows the release mechanism when a release actuator releases a hook of a quick release lock and thereby releases the instrument manipulator via a lock arm;

Fig. 7a shows an example of a configuration and construction of a release mechanism;

Fig. 7b shows a 3D isometric view of the release mechanism; and

Fig. 8 shows a cannula connector for coupling to a cannula, the cannula connector providing a through passage for a surgical instrument.

DETAILED DESCRIPTION OF EMBODIMENTS

[0030] It this section, it should be noted that for the sake of explanation, the entire robot has not been shown and some features of the robot, e.g., the linkage system and the movement of the instrument manipulator are explained in details. It is noted that the images show the instrument manipulator to operate on a right eye. For surgery on a left eye, the instrument manipulator may be positioned on the left side of a patient. In case of the left eye surgery, movements described herein may be mirrored with respect to the sagittal plane of the patient. It is noted that, in general, other tissues and organs may be the subject of the surgery and the robot is by no means limited to be used only in eye surgery. Fig. 1a shows a configuration of a linkage system 200 for moveably suspending an instrument manipulator 210 of a surgical master-slave robot. It is noted that the linkage system 200 and the instrument manipulator 210 are shown schematically and a cut through view in a transverse plane is shown. The linkage system 200 comprises a first linkage component 220 coupled to the instrument manipulator at a first suspension point 202 of the instrument manipulator 210. The first linkage component 220 may be configured for guiding the first suspension point 202 of the instrument manipulator 210 to move along a first movement trajectory. The linkage system 200 further comprises a second linkage component 230 coupled to the instrument manipulator 210 at a second suspension point 204 of the instrument manipulator 210. The second linkage component 230 may be configured for guiding the second suspension point 204 of the instrument manipulator 210 to move along a second movement trajectory.

[0031] Fig. 1b shows a translational and rotational movement of the instrument manipulator 210 obtained by rotation of a first rod member 220 and a second rod member 230 in a same direction of rotation. The first rod member 220 may be configured for guiding the first suspension point 202 of the instrument manipulator 210 to move along the first movement trajectory 260. The second linkage component 230 may be configured for guiding the second suspension point 204 of the instrument manipulator 210 to move along the second movement trajectory 270. The suspension point may be a point which couples the instrument manipulator 210 to the linkage system 200 by, for example, bolts and nuts, a hinge, a shaft, etc. In the illustrated configuration, the first rod member 220 may be initially in almost upright position, and the second rod member 230 may be in an angle of about 60°. Here and in the following, the angles are described with respect to 0° corresponding to a 3 o'clock position and 90° corresponding to a 12 o'clock position, i.e., denoting a counterclockwise rotation.

[0032] Both rod members 220,230 may rotate clockwise until the second rod member is substantially horizontal. With this configuration, a distal tip of the instrument manipulator or surgical instrument may be repositioned, for example, about 75 mm outwards and 70 mm downwards, moving the instrument manipulator 210 out of the surgeon's workspace 15 in a compact way.

[0033] It is noted that, with the claimed arrangement and configuration, upon a temporarily removal of the instrument manipulator, sufficient room for a surgeon may be provided while at the same time the instrument may remain compact and close to the surgeon to be returned when desired, without restricting the surgeon's performance. This effect may be achieved namely by combining translational and rotational movement of the instrument manipulator during the removal.

[0034] It is further noted that the first movement trajectory and the second movement trajectory differ and are selected to provide a combined translational and rotational movement of the instrument manipulator 210 from a surgical position proximate to a subject 10 to a standby position distal to the subject 10.

[0035] The standby position may be located lower than the subject 10 out of a surgeon's workspace 15 and the linkage system 240 may be configured for guiding the instrument manipulator 210 downward with respect to a coronal plane of the subject during the movement from the surgical position to the standby position. The standby position may be located laterally sideways with respect to a sagittal plane of the subject and the linkage system 240 may be configured for guiding the instrument manipulator 210 laterally sideward with respect to the sagittal plane during the movement from the surgical position to the standby position.

[0036] Fig. 1c shows an example of the instrument manipulator and the linkage system of the surgical master-slave robot 100 of Figs. 1a-b. It is noted that the same reference numerals in Fig. 1c and Figs. 1a-c refer to the same corresponding components.

[0037] It is noted that Figs. 1a-c, as well as Figs. 2a-5b, show a transverse view of the robot and the subject in a transverse plane. For further clarification of the movement of the instrument manipulator with respect to the subject 10 a sagittal plane 12 and a coronal plane 14 of the subject 10 are indicated in Fig. 1a. It is further noted that the linkage system may be coupled to a base 5 of the surgical robot which is schematically shown in Fig. 1a.

[0038] Figs. 2a-5b, show alternative arrangements and configurations of the linkage system and the instrument manipulator. Same or similar effects and results provided by the arrangement and configuration of Fig. 1 may be achieved.

[0039] Fig. 2a shows another configuration of a linkage system 300 for moveably suspending an instrument manipulator 310. Fig. 2b shows a translational and rotational movement of the instrument manipulator 310 obtained by rotation of a first rod member 320 and a second rod member 330 in opposite directions of rotation. The first rod member 320 may be configured for guiding the first suspension point 302 of the instrument manipulator 310 to move along the first movement trajectory 360. The second rod member 330 may be configured for guiding the second suspension point 304 of the instrument manipulator 310 to move along the second movement trajectory 370. In the illustrated configuration, the first rod member 320 may be, for example, in almost upright position and the second rod member 330 in an angle of approximately 135°. The first rod member 320 may rotate clockwise, while the second rod member counterclockwise.

[0040] Fig. 3a shows another configuration of a linkage system 400 for moveably suspending an instrument manipulator 410. Fig. 3b shows a translational and rotational movement of the instrument manipulator 410 obtained by a rotation of a first rod member 420 and a rotation of a second rod member 430 in a same direction of rotation. In the illustrated configuration, the first rod member 420 may be, for example, in horizontal orientation and the second rod member in an angle of approximately 135°. Both the first rod member and the second rod member may rotate counterclockwise.

[0041] Fig. 4a shows another configuration of a linkage system 500 for moveably suspending an instrument manipulator 510, wherein the first linkage component is a slider 520 and the second linkage component is a rod member 530. Fig. 4b shows a translational and rotational movement of the instrument manipulator 510 obtained by sliding of the slider 520 for moving a first suspension point 502 along a substantially straight movement trajectory 560 and by a rotation of the second rod member 530 for moving a second suspension point 504 along a second curved or arc-shaped movement trajectory 570.

[0042] Fig. 5a shows another configuration of a linkage system 600 for moveably suspending an instrument manipulator 610, wherein the first linkage component is a slider 620 and the second linkage component is a rod member 630. Fig. 5b shows a translational and rotational movement of the instrument manipulator 610 by a rotation of the rod member 630 and by sliding of the slider 620 along a curved path for moving a second suspension point 604 along a second curved or arc-shaped movement trajectory 670.

[0043] It is noted that in the illustrated configurations of Figs. 1a-5b, movement of the instrument manipulator 210, 310, 410,510, 610 may cause a tip of the instrument manipulator and/or a tip of the surgical instrument coupled to the instrument manipulator to move along a third movement trajectory 280, 380, 480, 580, 680. An end of the third movement trajectory proximate to the subject 10 may be in a direction 290, 390, 490, 590, 690, 790 substantially perpendicular to a surgical entry surface of the subject 10. It is noted that in the illustrated configuration of Figs. 1a-5b, the tip of the surgical instrument may be assumed to be substantially close to a tip of the instrument manipulator and hence surgical instrument is not separately indicated here. In general, however, there might be any desirable distance between the tip of the surgical instrument and the tip of the instrument manipulator.

[0044] It should be noted that in general, 2D or 3D configurations other than those illustrated herein may be possible for obtaining a desired movement of the instrument manipulator.

[0045] It is further noted that the movement of the instrument manipulator is according to the invention obtained as a result of a force, e.g. gravity force and/or spring force, acting upon the instrument manipulator when a release mechanism releases the instrument manipulator. In a further example, at least one of the first linkage component and the second linkage component may be provided with a manual actuation handle for enabling a user to manually actuate the linkage system so as to move the respective suspension point of the instrument manipulator along the respective movement trajectory. Various types of handles are known in the art per se. The handle may comprise a handgrip. It is noted that such an actuation handle may be used to put the instrument manipulator back in place at the surgical position by, e.g., pushing the instrument against gravity. In a further example, the surgical master-slave robot may also comprise an actuator for actuating the linkage system so as to move the respective suspension points of the instrument manipulator along the respective movement trajectory. Fig. 6a shows a release mechanism 700 for holding and releasing the instrument manipulator at a surgical position. The release mechanism may be affixed to the robot (not shown) and may be coupled to the instrument manipulator. By use of the release mechanism 700, the instrument manipulator is allowed to be released and then move sideways. The release mechanism 700 may comprise a hook 701, a lock arm pin 703, and a release actuator 704. The hook 701 may be arranged and configured for gripping the lock arm pin 703. It is noted that the hook may also be released manually. The lock arm pin may be connected to one of the first linkage component, the second linkage component or the instrument manipulator via a lock arm 702. The release actuator 704 may be arranged and configured for releasing the hook 701 from the lock arm pin 702. Fig. 6b shows the release mechanism 700 when the release actuator 704 releases the hook 701 and thereby releases the instrument manipulator via the lock arm 702. When released, a drive torque puts the instrument manipulator into motion. Such torque is applied passively by, e.g., use of storage of potential energy, via either a preloaded torsion spring or by the instrument manipulator's center of gravity. It is noted that the hook 701 may be preloaded via a spring 705 so that an engagement between the hook 701 and the arm lock pin 703 may be enabled when the lock arm 702 advances towards the quick release lock. When locked, the pin of the lock arm may be fixated, using a three-point connection further held in place by the hook 701. This may enable the instrument manipulator to be repositioned back into place with high accuracy. It is noted that the robot may comprises an actuator (not shown) for actuating the linkage system for repositioning of the instrument manipulator.

[0046] Fig. 7a shows an example of a configuration and construction of a release mechanism 800. The release mechanism 800 may comprise a first bore 810 in which two bearing balls 812 are positioned. The release mechanism 800 may further comprise a second bore 814 in which a reference pin 816 may be placed orthogonally and slightly offset. The bearing balls 812 may force against the reference pin 816, and as such, the bearing balls 812 may be precisely located. The bearing balls 812 may form a V-shaped reception 818 of a lock arm pin 803 of a lock arm 802. The V-shaped reception 818 may enable an accurate repositioning of the instrument manipulator. When locking, the lock arm pin 803 may be engaged into the V-shaped reception 818. The lock arm pin 816 may be enclosed by a release hook 801 and thus a three point constraint may be realized that may constrain the lock arm 802 in an X-Y plane only. The lock arm 802 may comprise a leaf spring or have a leaf spring shape (not shown) providing a compliance so as to enable the lock arm pin 803 to slide all the way into the V-shape reception 818. The bearing balls 812 and the pins 803, 816 may be made of hardened steel.

[0047] Fig. 7b shows a 3D isometric view of the release mechanism 800 of Fig. 7a.

[0048] Fig. 8 shows another aspect of the claimed surgical robot, namely a cannula connector 902 for coupling to a cannula 903, the cannula connector 902 providing a through passage 950 for a surgical instrument 904 to enter an interior of a tissue, e.g., any eye of a subject for, e.g., eye surgery. The cannula 903, also known as trocar in some surgical applications, may have on the proximal end an interface to the cannula connector 902 and on the distal end a tube that may be placed in an incision, e.g., the sclera in eye surgery. For example, in eye surgery, the cannula 903 may provide an opening or access point for vitreoretinal instruments to enter the eye. During surgery, multiple cannulas may be used, e.g., one for an infusion, one for a light fiber and one for an articulated instrument). The surgeon may use a microscope to look through the pupil inside the eye, seeing the surgical instrument tips.

[0049] The cannula connector 902 may be coupled at a proximal end to an instrument manipulator 910 of a surgical robot. For example, the cannula connector 902 may be coupled to the instrument manipulator 210 of the surgical robot 100 of Fig. 1c.. The cannula connector 902 may be shaped to fit a shape of the cannula 903 so as to establish a releasable coupling with the cannula 903 which releases when the instrument manipulator 910 moves away from an entry surface on the eye 10 of the subject in a substantially perpendicular direction 960. The cannula 903 and the cannula connector 902 may be made of medical grade materials: such as a selective group of stainless steel, titanium or plastics such as PEEK.

[0050] It is noted that in an example, the manipulator may be pushed onto the cannula with a predefined force. This force may be actively measured using a force sensor inside the cannula connector. In a further example, active mechanical clamping and releasing of the cannula may be used. When removing the instrument manipulator away from the area for surgery, the cannula may be loosening automatically. It is noted that active magnets may be also used which may be switched on and off automatically, to connect/disconnect the cannula to the cannula connector. Vacuum may be also used to suck to cannula to the cannula connector.

[0051] It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb "comprise" and its conjugations does not exclude the presence of elements or stages other than those stated in a claim. The article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements.

Claims

1. A surgical master-slave robot for use in minimally invasive surgery on a subject (10), the surgical master-slave robot comprising:

- an instrument manipulator (210, 310, 410,510, 610, 910) for mounting of a surgical instrument; and
- a linkage system (200, 300, 400, 500, 600) for moveably suspending the instrument manipulator, the linkage system comprising:
  - a first linkage component (220, 320, 420, 520, 620) coupled to the instrument manipulator at a first suspension point (202, 302, 402, 502, 602) of the instrument manipulator;
  - a second linkage component (230, 330, 430, 530, 630) coupled to the instrument manipulator at a second suspension point (204, 304, 404, 504, 604) of the instrument manipulator;

wherein:

- the first linkage component is configured for guiding the first suspension point of the instrument manipulator to move along a first movement trajectory (260, 360, 460, 560, 660);
- the second linkage component is configured for guiding the second suspension point of the instrument manipulator to move along a second movement trajectory (270, 370, 470, 570, 670); and wherein the first movement trajectory and the second movement trajectory differ and are selected to provide a combined translational and rotational movement of the instrument manipulator which moves the instrument manipulator along a predefined trajectory from a surgical position proximate to the subject to a standby position distal to the subject; **characterised in that**
- the surgical master-slave robot comprises a release mechanism for holding and releasing the instrument manipulator (210, 310, 410,510, 610, 910) at the surgical position; and
- the movement of the instrument manipulator from the surgical position to the standby position is obtained as a result of a force acting upon the instrument manipulator when the release mech-

anism releases the instrument manipulator, wherein the force is generated passively by conversion of stored potential energy.

2. The surgical master-slave robot according to claim 1, wherein said movement of the instrument manipulator causes a tip of a distal end of the instrument manipulator to move along a third movement trajectory (280, 380, 480, 580, 680), wherein an end portion of the third movement trajectory proximate to the subject is oriented in a direction (290, 390, 490, 590, 690, 790, 960) perpendicular to a surgical entry surface of the subject (10).

3. The surgical master-slave robot according to claim 1 or 2, wherein the standby position is located laterally sideways with respect to a sagittal plane of the subject (10) and the linkage system (200, 300, 400, 500, 600) is configured for guiding the instrument manipulator (210, 310, 410,510, 610, 910) laterally sideward with respect to the sagittal plane during the movement from the surgical position to the standby position.

4. The surgical master-slave robot according to any of the preceding claims, wherein the standby position is located lower than the subject (10) and the linkage system (200, 300, 400, 500, 600) is configured for guiding the instrument manipulator (210, 310, 410,510, 610, 910) downward with respect to a coronal plane of the subject during the movement from the surgical position to the standby position.

5. The surgical master-slave robot according to any of the preceding claims, wherein the force is generated by gravity and/or a preloaded spring.

6. The surgical master-slave robot according to any one of the preceding claims, wherein the release mechanism comprises a hook, a lock arm pin, and a release actuator, wherein:

- the hook is arranged and configured for gripping the lock arm pin; the lock arm pin being connected to one of the first linkage component, the second linkage component or the instrument manipulator via a lock arm;
- the release actuator is arranged and configured for releasing the hook from the lock arm pin.

7. The surgical master-slave robot according to any of claims 1 to 6, wherein the linkage system is provided with a manual actuation handle for enabling a user to manually actuate the linkage system so as to move the respective suspension point of the instrument manipulator (210, 310, 410,510, 610, 910) along the respective movement trajectory.

8. The surgical master-slave robot according to any of claims 1 to 6, wherein the surgical master-slave robot comprises an actuator for actuating the linkage system so as to move the respective suspension point of the instrument manipulator along the respective movement trajectory.

9. The surgical master-slave robot according to any of the preceding claims, wherein at least one of the first linkage component (220, 320, 420, 520, 620) and the second linkage component (230, 330, 430, 530, 630) comprises or is constituted by a slider for sliding along a guide shaped to establish the respective movement trajectory.

10. The surgical master-slave robot according to any of claims 1 to 8, wherein the first linkage component (220, 320, 420, 520, 620) and the second linkage component (230, 330, 430, 530, 630) each are rod members rotatable about a respective rotation point and having different lengths, and a rotation of the first linkage component and the second linkage component about the respective rotation points provides said movement of the respective suspension point along the respective movement trajectory.

11. The surgical master-slave robot according to any of the preceding claims, wherein one or both of the first movement trajectory (260, 360, 460, 560, 660) and the second movement trajectory (270, 370, 470, 570, 670) are curve- or arc-shaped movement trajectories

12. The surgical master-slave robot according to any of the preceding claims in as far as dependent on claim 2, wherein the surgical master-slave robot (100) further comprises a cannula connector (902) for coupling to a cannula (903), wherein the cannula (903) provides an opening at the surgical entry surface of the subject (10) for the surgical instrument (904) to enter an interior of the subject (10), and wherein the cannula connector (902):

- is coupled to the instrument manipulator (210, 310, 410,510, 610, 910) at a proximal end;
- comprises a through passage (950) for allowing the surgical instrument (904) to pass through the through passage (950); and
- is shaped to fit a shape of the cannula (903) so as to establish a releasable coupling with the cannula (903) which releases when the instrument manipulator (210, 310, 410,510, 610, 910) moves in the direction (290, 390, 490, 590, 690, 790, 960) perpendicular to the surgical entry surface of the subject (10).

13. The surgical master-slave robot according to claim 12, wherein the cannula (1008) has a conical shape and wherein the cannula connector (902) is conically

shaped to fit the conical shape of the cannula (903).

14. The surgical master-slave robot according to claim 12 or 13, wherein the cannula (903) and the cannula connector (902) are rigidly coupled.

Patentansprüche

1. Ein chirurgischer Master-Slave-Roboter zur Verwendung in minimal invasiver Chirurgie an einem Subjekt (10), wobei der Master-Slave-Roboter umfasst:

- einen Instrumentenmanipulator (210, 310, 410, 510, 610, 910) zur Montage eines chirurgischen Instruments; und
- ein Verbindungssystem (200, 300, 400, 500, 600) zum beweglichen Aufhängen des Instrumentenmanipulators, wobei das Verbindungssystem umfasst:

    - eine erste Verbindungskomponente (220, 320, 420, 520, 620), die an den Instrumentenmanipulator an einem ersten Aufhängungspunkt (202, 302, 402, 502, 602) des Instrumentenmanipulators gekoppelt ist;
    - eine zweite Verbindungskomponente (230, 330, 430, 530, 630), die an den Instrumentenmanipulator an einem zweiten Aufhängungspunkt (204, 304, 404, 504, 604) des Instrumentenmanipulators gekoppelt ist;

wobei:
- die erste Verbindungskomponente zum Führen des ersten Aufhängungspunkts des Instrumentenmanipulators, um sich entlang einer ersten Bewegungsbahn (260, 360, 460, 560, 660) zu bewegen, ausgebildet ist;
- die zweite Verbindungskomponente zum Führen des zweiten Aufhängungspunkts des Instrumentenmanipulators, um sich entlang einer zweiten Bewegungsbahn (270, 370, 470, 570, 670) zu bewegen, ausgebildet ist; und wobei die erste Bewegungsbahn und die zweite Bewegungsbahn unterschiedlich sind und ausgewählt sind, um eine kombinierte Verschiebungs- und Drehbewegung des Instrumentenmanipulators bereitzustellen, die den Instrumentenmanipulator entlang einer vordefinierten Bahn von einer chirurgischen Position nahe dem Subjekt zu einer Bereitschaftsposition fern dem Subjekt bewegt; **dadurch gekennzeichnet, dass**
- der chirurgische Master-Slave-Roboter einen Freigabemechanismus zum Halten und Freigeben des Instrumentenmanipulators (210, 310, 410, 510, 610, 910) an der chirurgischen Position umfasst; und
- die Bewegung des Instrumentenmanipulators aus der chirurgischen Position in die Bereitschaftsposition infolge einer Kraft erhalten wird, die auf den Instrumentenmanipulator wirkt, wenn der Freigabemechanismus den Instrumentenmanipulator freigibt, wobei die Kraft passiv durch Umwandeln gespeicherter potenzieller Energie erzeugt wird.

2. Der chirurgische Master-Slave-Roboter nach Anspruch 1, wobei die Bewegung des Instrumentenmanipulators bewirkt, dass sich eine Spitze eines distalen Endes des Instrumentenmanipulators entlang einer dritten Bewegungsbahn (280, 380, 480, 580, 680) bewegt, wobei ein Endabschnitt der dritten Bewegungsbahn nahe dem Subjekt in einer Richtung (290, 390, 490, 590, 690, 790, 960) senkrecht zu einer chirurgischen Eintrittsfläche des Subjekts (10) ausgerichtet ist.

3. Der chirurgische Master-Slave-Roboter nach Anspruch 1 oder 2, wobei die Bereitschaftsposition lateral zur Seite in Bezug auf die sagittale Ebene des Subjekts (10) liegt und das Verbindungssystem (200, 300, 400, 500, 600) gestaltet ist, den Instrumentenmanipulator (210, 310, 410, 510, 610, 910) während der Bewegung von der chirurgischen Position zu der Bereitschaftsposition lateral zur Seite in Bezug auf die sagittale Ebene zu führen.

4. Der chirurgische Master-Slave-Roboter nach einem der vorstehenden Ansprüche, wobei die Bereitschaftsposition tiefer liegt als das Subjekt (10) und das Verbindungssystem (200, 300, 400, 500, 600) gestaltet ist, den Instrumentenmanipulator (210, 310, 410, 510, 610, 910) während der Bewegung von der chirurgischen Position zu der Bereitschaftsposition in Bezug auf die koronale Ebene des Subjekts nach unten zu bewegen.

5. Der chirurgische Master-Slave-Roboter nach einem der vorstehenden Ansprüche, wobei die Kraft durch Schwerkraft und/oder eine vorbelastete Feder erzeugt wird.

6. Der chirurgische Master-Slave-Roboter nach einem der vorstehenden Ansprüche, wobei der Freigabemechanismus einen Haken, einem Verriegelungsarmstift und ein Freigabestellglied umfasst, wobei:

- der Haken angeordnet und gestaltet ist, den Verriegelungsarmstift zu ergreifen; der Verriegelungsarmstift mit einem der ersten Verbindungskomponente, der zweiten Verbindungskomponente oder dem Instrumentenmanipulator über einen Verriegelungsarm verbunden ist;
- das Freigabestellglied angeordnet und gestal-

tet ist, den Haken von dem Verriegelungsarmstift freizugeben.

7. Der chirurgische Master-Slave-Roboter nach einem der Ansprüche 1 bis 6, wobei das Verbindungssystem mit einem manuellen Betätigungsgriff versehen ist, um einem Benutzer zu ermöglichen, das Verbindungssystem manuell zu betätigen, um so den entsprechenden Aufhängungspunkt des Instrumentenmanipulators (210, 310, 410, 510, 610, 910) entlang der entsprechenden Bewegungsbahn zu bewegen.

8. Der chirurgische Master-Slave-Roboter nach einem der Ansprüche 1 bis 6, wobei der chirurgische Master-Slave-Roboter ein Stellglied zum Betätigen des Verbindungssystems umfasst, um so den entsprechenden Aufhängungspunkt des Instrumentenmanipulators entlang der entsprechenden Bewegungsbahn zu bewegen.

9. Der chirurgische Master-Slave-Roboter nach einem der vorstehenden Ansprüche, wobei mindestens eine der ersten Verbindungskomponente (220, 320, 420, 520, 620) und der zweiten Verbindungskomponente (230, 330, 430, 530, 630) einen Schieber umfasst oder durch diesen gebildet ist, zur Gleitbewegung entlang einer Führung, die geformt ist, die entsprechende Bewegungsbahn zu errichten.

10. Der chirurgische Master-Slave-Roboter nach einem der Ansprüche 1 bis 8, wobei die erste Verbindungskomponente (220, 320, 420, 520, 620) und die zweite Verbindungskomponente (230, 330, 430, 530, 630) jeweils Stabelemente sind, die um einen entsprechenden Drehpunkt drehbar sind und verschiedene Längen aufweisen, und eine Drehung der ersten Verbindungskomponente und der zweiten Verbindungskomponente um die entsprechenden Drehpunkte die Bewegung des entsprechenden Aufhängungspunkts entlang der entsprechenden Bewegungsbahn vorsieht.

11. Der chirurgische Master-Slave-Roboter nach einem der vorstehenden Ansprüche, wobei eine oder beide der ersten Bewegungsbahn (260, 360, 460, 560, 660) und der zweiten Bewegungsbahn (270, 370, 460, 570, 670) krumme oder bogenförmige Bewegungsbahnen sind.

12. Der chirurgische Master-Slave-Roboter nach einem der vorstehenden Ansprüche, insofern als von Anspruch 2 abhängig, wobei der chirurgische Master-Slave-Roboter (100) weiter einen Kanülenverbinder (902) zur Kopplung an eine Kanüle (903) umfasst, wobei die Kanüle (903) eine Öffnung an der chirurgischen Eintrittsfläche des Subjekts (10) für das chirurgische Instrument (904) vorsieht, um in ein Inneres des Subjekts (10) zu gelangen, und wobei der Kanülenverbinder (902):

- an den Instrumentenmanipulator (210, 310, 410, 510, 610, 910) an einem proximalen Ende gekoppelt ist;
- einen Durchgang (950) umfasst, um dem chirurgischen Instrument (904) ein Hindurchgehen durch den Durchgang (950) zu ermöglichen; und
- geformt ist, um zu einer Form der Kanüle (903) zu passen, um so eine lösbare Kopplung mit der Kanüle (903) zu errichten, die freigegeben wird, wenn sich der Instrumentenmanipulator (210, 310, 410, 510, 610, 910) in die Richtung (290, 390, 490, 590, 790, 960) senkrecht zu der chirurgischen Eintrittsfläche des Subjekts (10) bewegt.

13. Der chirurgische Master-Slave-Roboter nach Anspruch 12, wobei die Kanüle (1008) eine konische Form aufweist und wobei der Kanülenverbinder (902) konisch geformt ist, um zu der konischen Form der Kanüle (903) zu passen.

14. Der chirurgische Master-Slave-Roboter nach Anspruch 12 oder 13, wobei die Kanüle (903) und der Kanülenverbinder (902) starr gekoppelt sind.

Revendications

1. Un robot chirurgical maître-esclave pour une utilisation en chirurgie minimalement invasive sur un sujet (10), le robot chirurgical maître-esclave comprenant :

   - un manipulateur d'instrument (210, 310, 410, 510, 610, 910) pour le montage d'un instrument chirurgical ; et
   - un système de liaison (200, 300, 400, 500, 600) pour la suspension mobile du manipulateur d'instrument, le système de liaison comprenant :

     - un premier composant de liaison (220, 320, 420, 520, 620) couplé au manipulateur d'instrument au niveau d'un premier point de suspension (202, 302, 402, 502, 602) du manipulateur d'instrument ;
     - un second composant de liaison (230, 330, 430, 530, 630) couplé au manipulateur d'instrument au niveau d'un second point de suspension (204, 304, 404, 504, 604) du manipulateur d'instrument ;

   dans lequel :

   - le premier composant de liaison est configuré pour guider le premier point de suspension du manipulateur d'instrument pour le déplacer le long d'une première trajectoire de mouvement (260, 360, 460, 560, 660) ;

- le second composant de liaison est configuré pour guider le second point de suspension du manipulateur d'instrument pour le déplacer le long d'une deuxième trajectoire de mouvement (270, 370, 470, 570, 670) ; et dans lequel la première trajectoire de mouvement et la deuxième trajectoire de mouvement diffèrent et sont sélectionnées pour fournir un mouvement combiné de translation et de rotation du manipulateur d'instrument qui déplace le manipulateur d'instrument le long d'une trajectoire prédéfinie d'une position chirurgicale à proximité du sujet à une position d'attente à distance du sujet ; **caractérisé en ce que**

- le robot chirurgical maître-esclave comprend un mécanisme de libération pour maintenir et libérer le manipulateur d'instrument (210, 310, 410, 510, 610, 910) au niveau de la position chirurgicale ; et

- le mouvement du manipulateur d'instrument de la position chirurgicale à la position d'attente est obtenu en résultant d'une force agissant sur le manipulateur d'instrument lorsque le mécanisme de libération libère le manipulateur d'instrument, dans lequel la force est générée passivement par conversion d'énergie potentielle stockée.

2. Le robot chirurgical maître-esclave selon la revendication 1, dans lequel ledit mouvement du manipulateur d'instrument amène une pointe d'une extrémité distale du manipulateur d'instrument à se déplacer le long d'une troisième trajectoire de mouvement (280, 380, 480, 580, 680), dans lequel une portion d'extrémité de la troisième trajectoire de mouvement à proximité du sujet est orientée dans une direction (290, 390, 490, 590, 690, 790, 960) perpendiculaire à une surface d'entrée chirurgicale du sujet (10).

3. Le robot chirurgical maître-esclave selon la revendication 1 ou 2, dans lequel la position d'attente est située latéralement sur les côtés par rapport à un plan sagittal du sujet (10) et le système de liaison (200, 300, 400, 500, 600) est configuré pour guider le manipulateur d'instrument (210, 310, 410, 510, 610, 910) latéralement vers les côtés par rapport au plan sagittal pendant le mouvement de la position chirurgicale à la position d'attente.

4. Le robot chirurgical maître-esclave selon l'une quelconque des revendications précédentes, dans lequel la position d'attente est située plus bas que le sujet (10) et le système de liaison (200, 300, 400, 500, 600) est configuré pour guider le manipulateur d'instrument (210, 310, 410, 510, 610, 910) vers le bas par rapport à un plan coronal du sujet pendant le mouvement de la position chirurgicale à la position d'attente.

5. Le robot chirurgical maître-esclave selon l'une quelconque des revendications précédentes, dans lequel la force est générée par gravité et/ou un ressort précontraint.

6. Le robot chirurgical maître-esclave selon l'une quelconque des revendications précédentes, dans lequel le mécanisme de libération comprend un crochet, une broche de bras de verrouillage et un actionneur de libération, dans lequel :

- le crochet est agencé et configuré pour saisir la broche de bras de verrouillage ; la broche de bras de verrouillage étant connectée à l'un du premier composant de liaison, du second composant de liaison ou du manipulateur d'instrument par l'intermédiaire d'un bras de verrouillage ;

- l'actionneur de libération est agencé et configuré pour libérer le crochet de la broche de bras de verrouillage.

7. Le robot chirurgical maître-esclave selon l'une quelconque des revendications 1 à 6, dans lequel le système de liaison est doté d'une poignée à actionnement manuel pour permettre à un utilisateur d'actionner manuellement le système de liaison de façon à déplacer le point de suspension respectif du manipulateur d'instrument (210, 310, 410, 510, 610, 910) le long de la trajectoire de mouvement respective.

8. Le robot chirurgical maître-esclave selon l'une quelconque des revendications 1 à 6, dans lequel le robot chirurgical maître-esclave comprend un actionneur pour actionner le système de liaison de façon à déplacer le point de suspension respectif du manipulateur d'instrument le long de la trajectoire de mouvement respective.

9. Le robot chirurgical maître-esclave selon l'une quelconque des revendications précédentes, dans lequel au moins l'un du premier composant de liaison (220, 320, 420, 520, 620) et du second composant de liaison (230, 330, 430, 530, 630) comprend ou est constitué d'un coulisseau pour coulisser le long d'un guide façonné pour établir la trajectoire de mouvement respective.

10. Le robot chirurgical maître-esclave selon l'une quelconque des revendications 1 à 8, dans lequel le premier composant de liaison (220, 320, 420, 520, 620) et le second composant de liaison (230, 330, 430, 530, 630) sont chacun des éléments de tige pouvant tourner autour d'un point de rotation respectif et présentant différentes longueurs, et une rotation du premier composant de liaison et du second composant de liaison autour des points de rotation respectifs fournit ledit mouvement du point de suspension respectif le long de la trajectoire de mouvement respective.

11. Le robot chirurgical maître-esclave selon l'une quelconque des revendications précédentes, dans lequel l'une ou les deux de la première trajectoire de mouvement (260, 360, 460, 560, 660) et de la deuxième trajectoire de mouvement (270, 370, 470, 570, 670) sont des trajectoires de mouvement en forme de courbe ou d'arc.

12. Le robot chirurgical maître-esclave selon l'une quelconque des revendications précédentes dans la mesure où elles dépendent de la revendication 2, dans lequel le robot chirurgical maître-esclave (100) comprend en outre un connecteur de canule (902) pour un couplage à une canule (903), dans lequel la canule (903) fournit une ouverture au niveau de la surface d'entrée chirurgicale du sujet (10) pour que l'instrument chirurgical (904) entre dans un intérieur du sujet (10), et dans lequel le connecteur de canule (902) :

- est couplé au manipulateur d'instrument (210, 310, 410, 510, 610, 910) au niveau d'une extrémité proximale ;
- comprend un passage traversant (950) pour permettre à l'instrument chirurgical (904) de passer à travers le passage traversant (950) ; et
- est façonné pour s'adapter à une forme de la canule (903) de façon à établir un couplage libérable avec la canule (903) qui se libère lorsque le manipulateur d'instrument (210, 310, 410, 510, 610, 910) se déplace dans la direction (290, 390, 490, 590, 690, 790, 960) perpendiculaire à la surface d'entrée chirurgicale du sujet (10).

13. Le robot chirurgical maître-esclave selon la revendication 12, dans lequel la canule (1008) a une forme conique et dans lequel le connecteur de canule (902) est de forme conique pour s'adapter à la forme conique de la canule (903).

14. Le robot chirurgical maître-esclave selon la revendication 12 ou 13, dans lequel la canule (903) et le connecteur de canule (902) sont couplés de manière rigide.

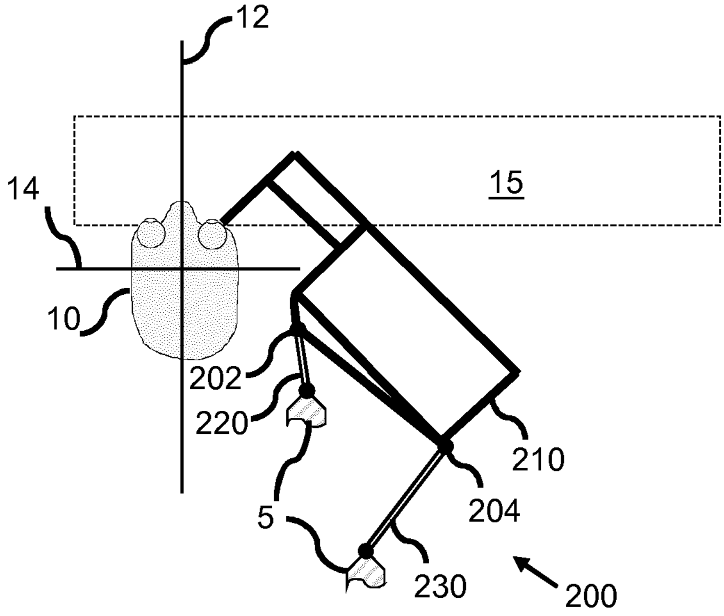
12
14
15
10
202
220
5
210
204
230
200

Fig. 1a

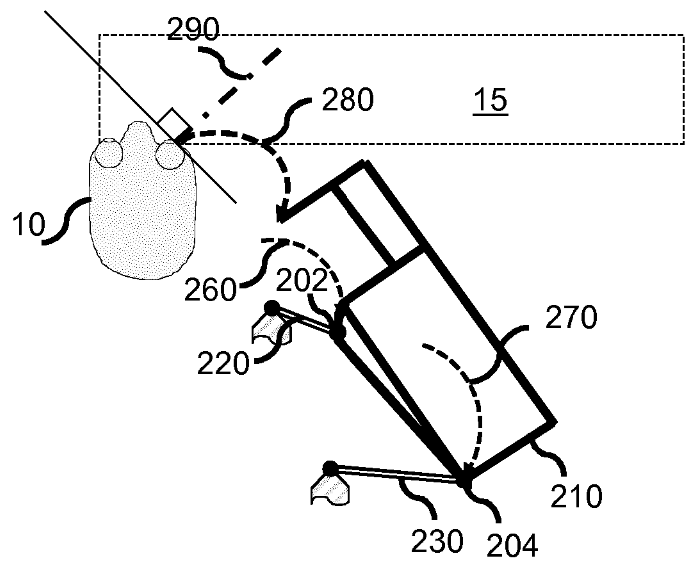
290
280
15
10
260
202
270
220
210
230
204

Fig. 1b

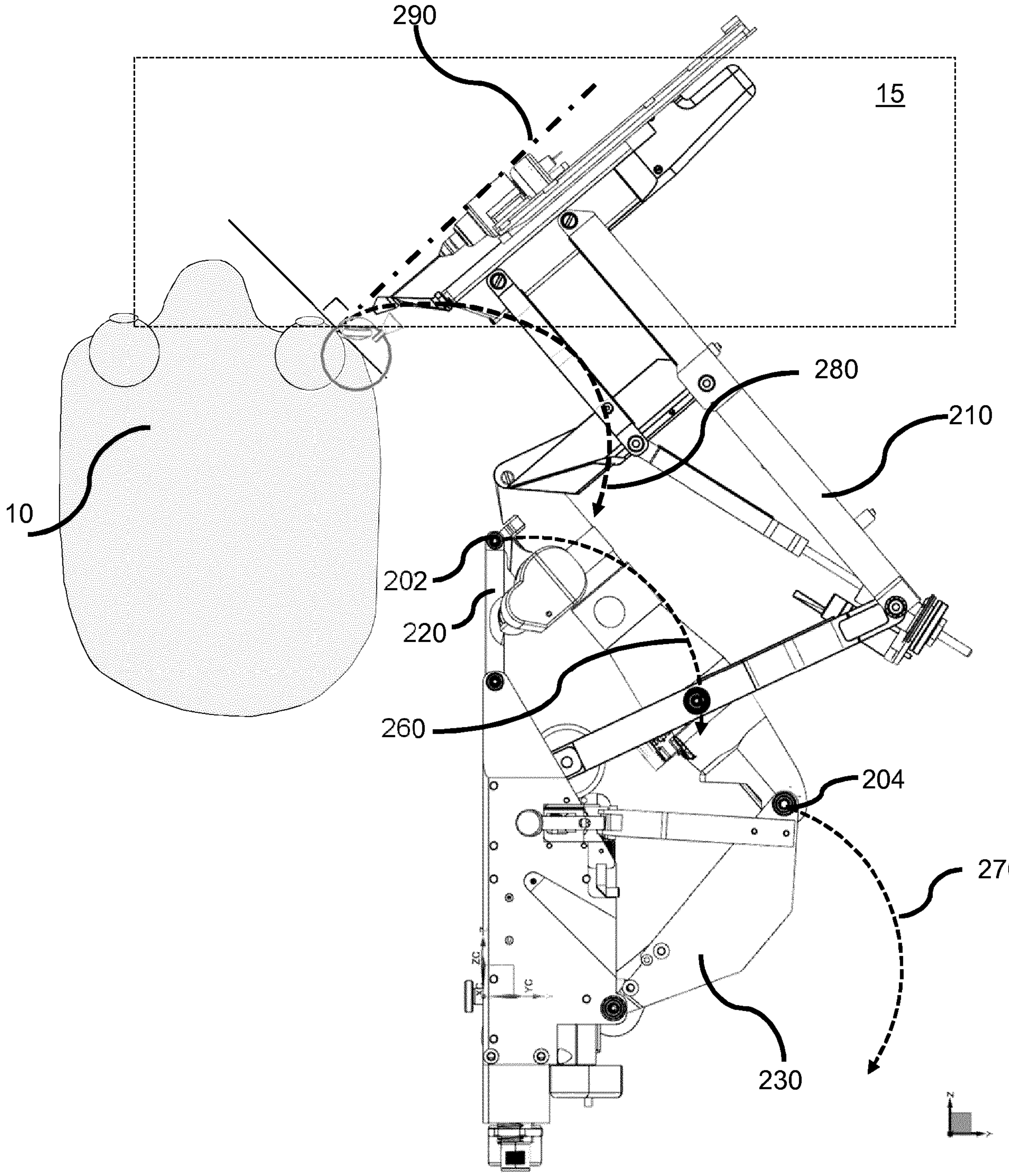

Fig. 1c

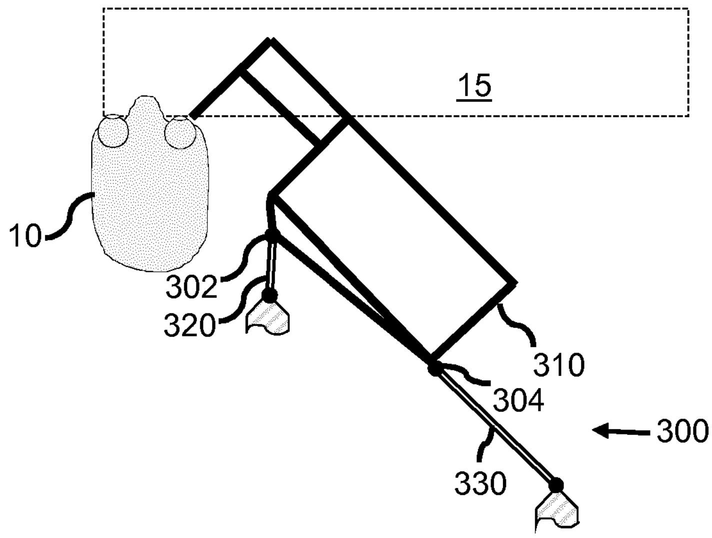
15
10
302
320
310
304
300
330

Fig. 2a

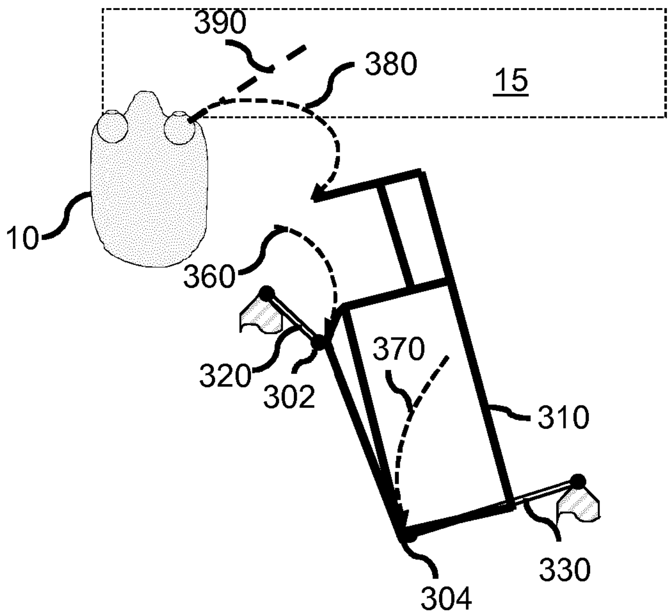
390
380
15
10
360
370
320
302
310
330
304

Fig. 2b

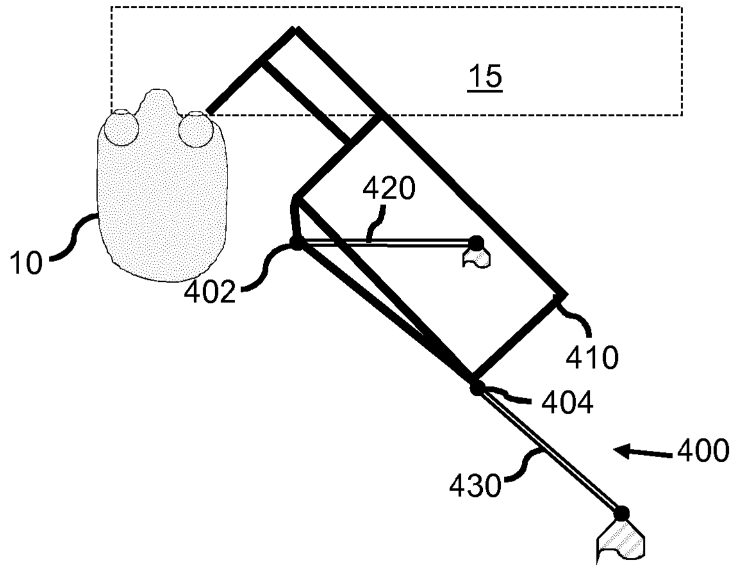
15
420
10
402
410
404
400
430

Fig. 3a

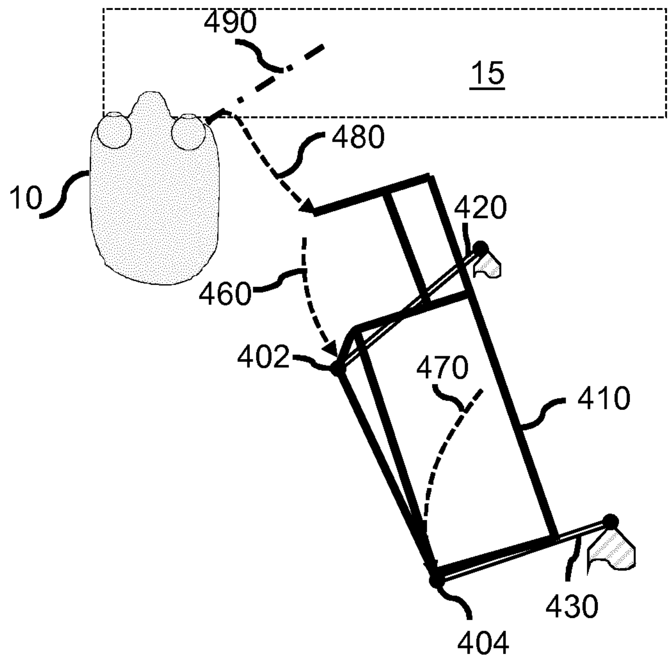
490
15
480
10
420
460
402
470
410
430
404

Fig. 3b

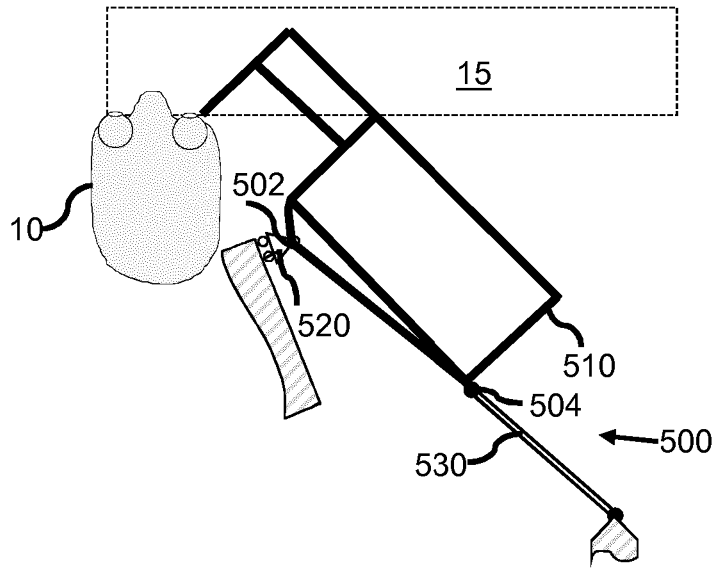
15
502
10
520
510
504
500
530

Fig. 4a

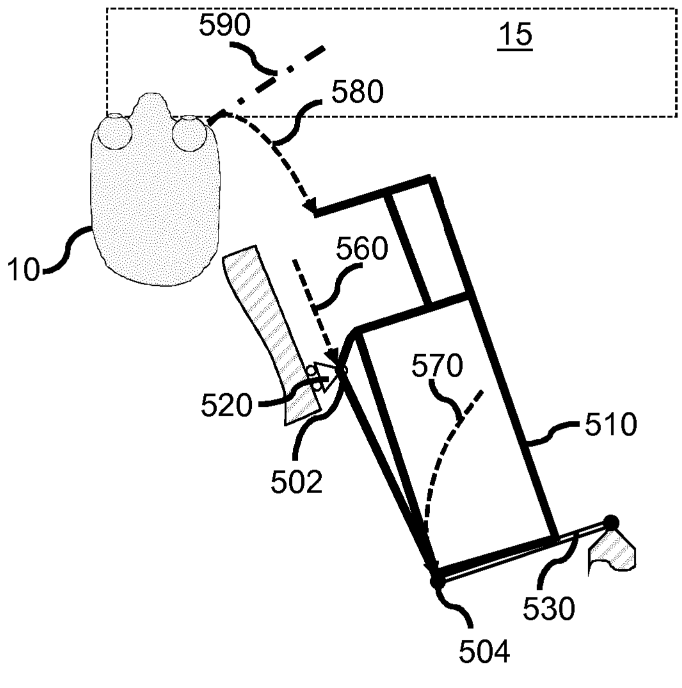
590
15
580
10
560
570
520
510
502
530
504

Fig. 4b

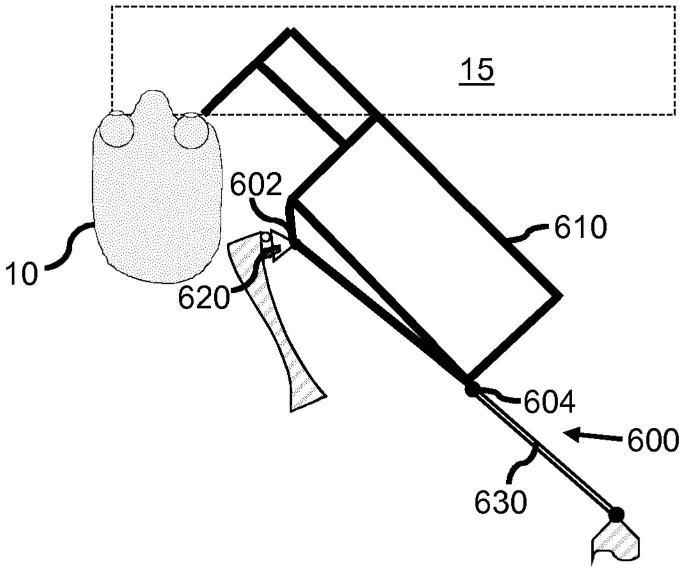
15
602
610
10
620
604
600
630

Fig. 5a

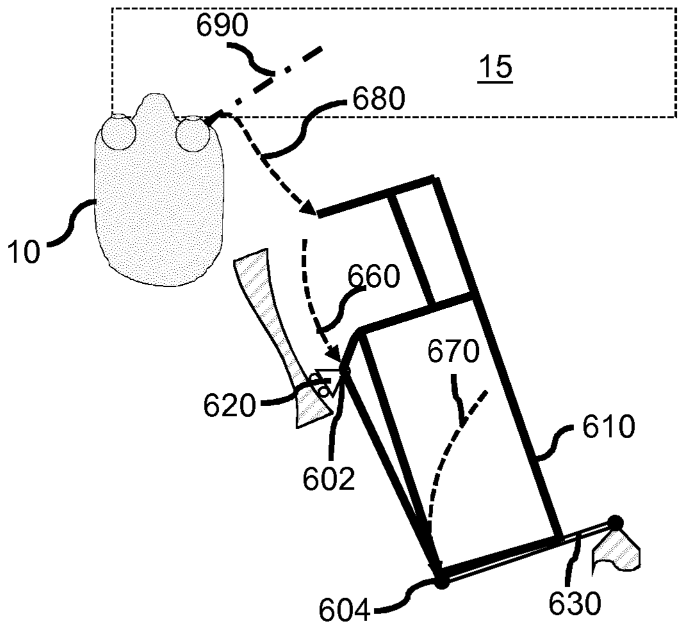
690
15
680
10
660
670
620
610
602
604
630

Fig. 5b

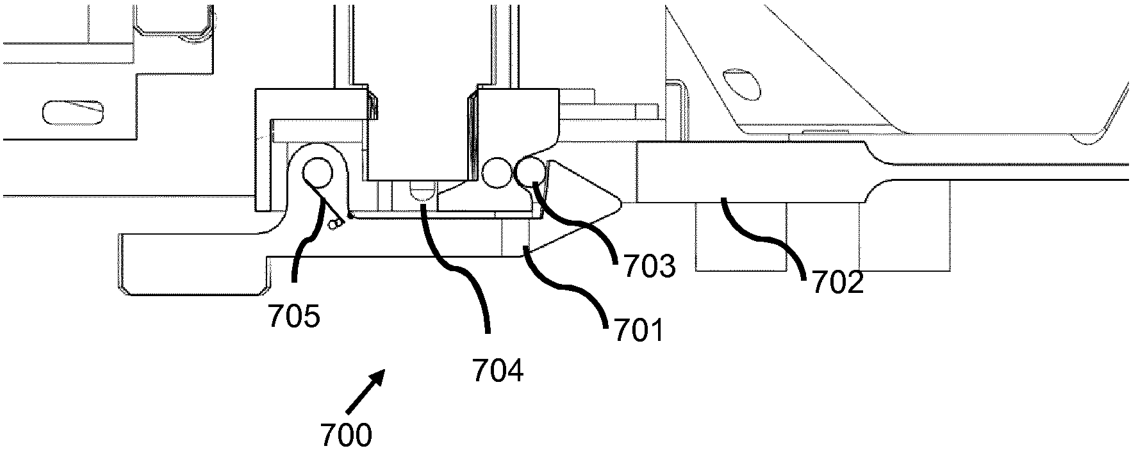

Fig. 6a

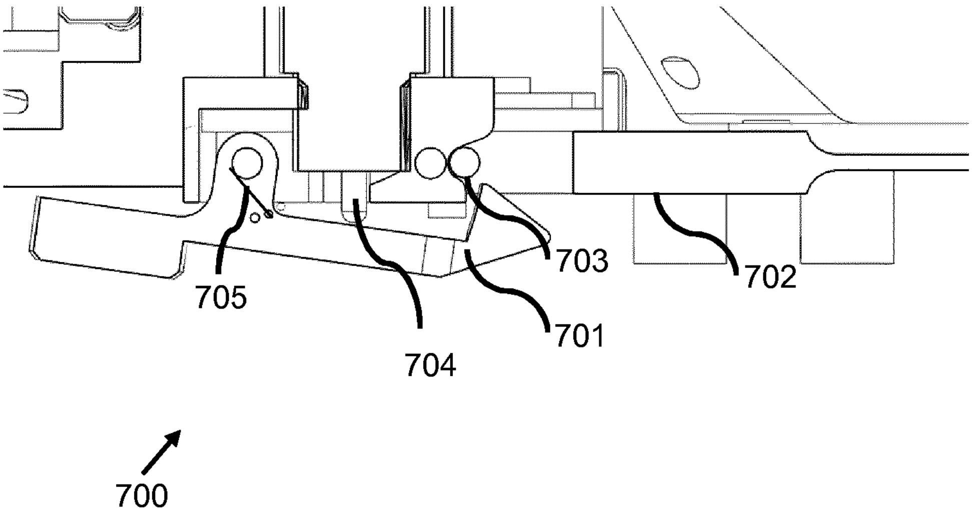

Fig. 6b

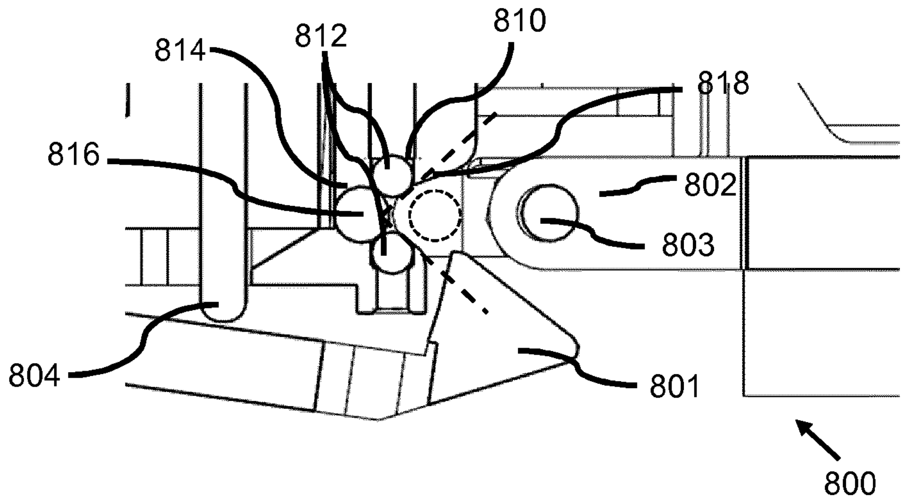
814
812
810
818
816
802
803
804
801
800

Fig. 7a

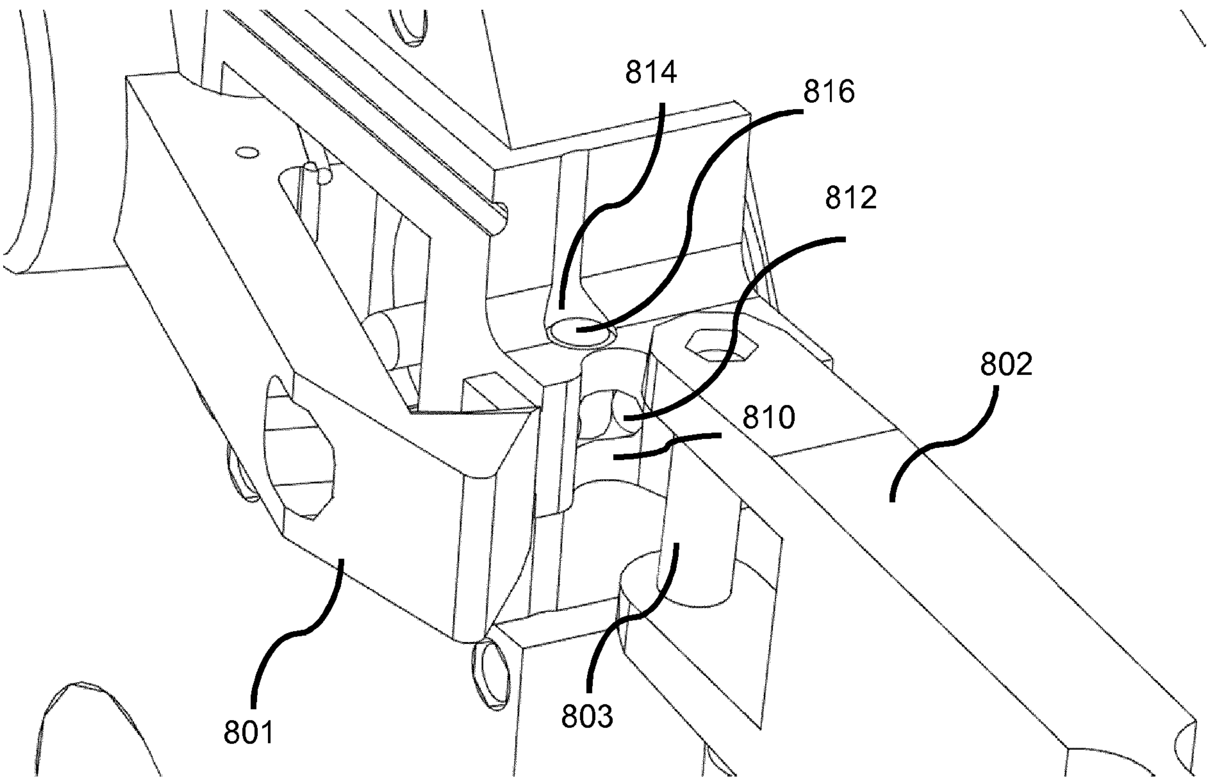
814
816
812
802
810
801
803

Fig. 7b

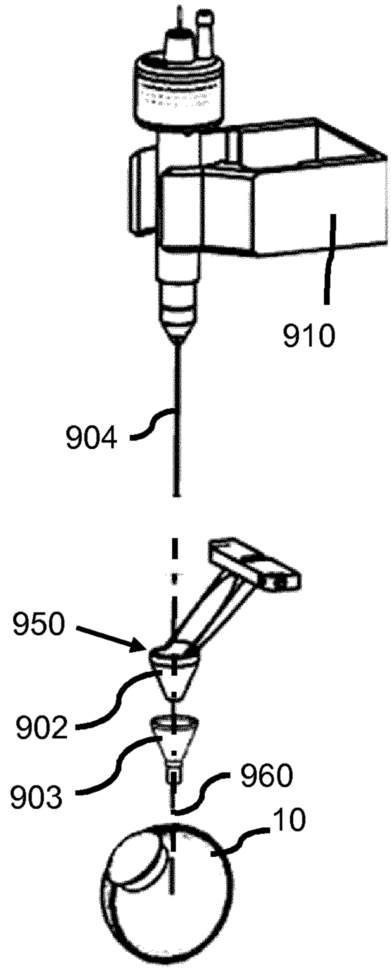

Fig. 8

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 20040261179 A1 **[0003]**
- WO 0030557 A1 **[0004]**
- US 2015245875 A1 **[0004]**
- WO 9510218 A1, ALI UNERI **[0004]**
- WO 9639944 A1 **[0004]**